INDOOR AIR QUALITY ASSESSMENT

Weston Fire Department
Station 2
390 South Ave, Route 30
Weston, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Carl Valente, (former) Town Manager for the town of Weston and the Weston Fire Fighters Union, the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health was asked to provide assistance and consultation regarding indoor air quality concerns at the Weston Fire Department (WFD), Station 2 located at 390 South Ave/Route 30, Weston, Massachusetts.

On May 12, 2005, a visit was made to Station 2 by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program to conduct an indoor air quality assessment. Mr. Holmes was accompanied by Ed Walker, Chief, WFD and Chris Macmillan, WFD, during the assessment. The request was prompted by mold concerns related to water damage in the building.

Station 2 is a single-story red brick building that was constructed in 1968. The building has never been renovated, therefore the majority of building materials (e.g., floors, ceiling tiles) are original. Station 2 contains an engine bay (housing three response vehicles), the watch room, a workshop/laundry room, storage rooms, berthing areas and a kitchen/lounge area. The basement contains the heating plant and is used for storage.

At the time of the assessment Chief Walker reported that renovations to Station 2 were planned and would begin approximately one week after the MDPH visit. These renovations were to include total replacement of the roof, ceiling tile systems and sealing of the building envelope (e.g., brick repointing, window caulking and flashing replacement). In subsequent correspondence with Captain Walker on July 6, 2005, he reported that replacement of the roofs at WFD station 2 and headquarters, were being conducted. Work was scheduled to be completed in August 2005. In subsequent correspondence with Captain Walker on September 16, 2005, he reported that replacement of the roofs at WFDHQ and station 2, which is located at 390 South Ave, Rt. 30, was being completed.

Methods

Air tests for carbon dioxide, carbon monoxide (CO), temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525. MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of approximately 8 (2 per shift). The station is visited by up to 5-10 members of the public on a daily basis. The tests were taken during normal operations. Test results for general air quality parameters (e.g., carbon dioxide, temperature and relative humidity) appear in Table 1. Test results for UFPs and CO are listed in Table 2.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, indicating adequate air exchange (Table 1). However, it is important to note that the station does not have any means of mechanical ventilation but uses windows to introduce fresh air. A vehicle exhaust ventilation system is installed in the engine bay to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings were measured in a range of 63^{o} F to 68^{o} F, which were below the MDPH recommended comfort range (Table 1). The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 30 to 46 percent, with the majority of areas below the MDPH recommended comfort guidelines (Table 1). The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The station has reportedly experienced problems with water penetration through the roof and building envelope. Water-damaged ceiling tiles and fiberglass insulation were observed throughout the station (Pictures 1 to 3). Water-damaged porous building materials can provide a source of mold and should be replaced after a leak is discovered and repaired. Visible mold growth was observed on the paper backing of fiberglass insulation in the main hallway (Picture 3). Visible mold growth was also observed on pipe wrapping in the basement (Picture 4). The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials (e.g. wallboard, ceiling tiles, carpeting) be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed.

MDPH staff examined the outside perimeter of the building to identify breaches in the building envelope that could provide a source of water penetration. A number of exterior sources for moisture were identified:

- Discoloration and moss growth was seen on brick along the front wall of the building, indicating an area of chronic water accumulation/backsplashing. The water appears to roll off the peaked roof over the front entrance, which is not equipped with a gutter system (Pictures 5 and 6).
- The basement entrance at the rear of the building is equipped with a drain, which was clogged with leaves and debris (Picture 7). Water accumulation and penetration was evident in this area due to severe corrosion of a wooden door located at the rear of the building, as a result the door was sealed with plastic sheeting (Picture 8).
- Spaces, missing/damaged mortar around masonry was observed at the rear of the building (Pictures 9 and 10), and
- Open utility holes (Pictures 11 and 12) and spaces around window frames were seen around the exterior of the building (Pictures 13 and 14).

These conditions can undermine the integrity of the building envelope and provide a means of water entry by capillary action into the building through exterior walls, foundation concrete and masonry (Lstiburek & Brennan, 2001).

Vehicle Exhaust

Under normal conditions, a firehouse can have several sources of environmental pollutants present from the operation of fire vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds;
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Residues from fires on vehicles, hoses and fire-turnout gear.

Of particular importance is vehicle exhaust. In order to assess whether contaminants generated by diesel engines were migrating into occupied areas of the station, measurements for airborne particulates in combination with carbon monoxide measurements were taken.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). *Carbon monoxide should not be present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 2). Carbon monoxide levels in the station were also ND (Table 2).

The combustion of fossil fuels can produce particulate matter that is of a small diameter (10 μm), which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas. Inhaled particles can cause respiratory irritation.

MDPH air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, in that it can be used as a tracker to identify the source of airborne pollutants by counting the actual number of airborne particles. The source of a producer of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increases as the UPC is moved closer to the source of particle production.

The primary purpose of these tests at the station was to identify and reduce/prevent pollutant pathways. Air monitoring for ultrafine particles was conducted around each door with access to the engine bay as well as several areas within the station. Measurements were taken prior to and after diesel engine operation. The highest reading for UFPs was taken in the engine bay after vehicle operation. These measurements would be expected during the normal operation of motor vehicles in an indoor environment. However, several elevated readings were measured in adjacent areas identifying pathways for the migration of vehicle exhaust into occupied areas (Table 2).

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling (Picture 15). The system in use at the station connects directly to the tail pipe of the engine via a pressurized cuff (Picture 16). As the vehicle exits the station, the cuff, which is pulled on a runner, trips a trigger releasing the cuff. The system is designed to collect vehicle exhaust directly at the source and remove it from the building, minimizing exposure. Although the engine bay is equipped with local exhaust ventilation, a number of pathways for vehicle exhaust and other pollutants to move from the engine bay into occupied areas were identified (Figure 1). The doors (off the engine bay) leading to the compressor room and watch station had spaces beneath the door and light could be seen penetrating into the stairwell through these spaces (Picture 17).

Another possible pathway for exhaust emissions is through utility holes. The walls of the engine bays are penetrated by utility holes. These holes can present potential pathways into occupied areas if they are not airtight. Each of these pathways can allow air to move from the engine bay to occupied areas of the station. In order to explain how engine bay pollutants may be impacting adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of pollutants to adjacent areas. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bays can place the bays under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into adjacent areas, sealing of these potential or identified pollutant pathways should be considered.

Other Concerns

Several other conditions that can potentially affect indoor air quality were identified. Damaged/exposed pipe insulation was observed in the basement (Pictures 18 and 19). The pipe insulation may contain asbestos. At the time of the assessment MDPH staff recommended that the material be encapsulated by a licensed member of the Weston town maintenance staff or other professional contractor as soon as practicable.

Finally, local exhaust ventilation in restrooms was not functioning during the assessment. Several of the vents were blocked with cardboard presumably to prevent drafts from backdrafting (Picture 20). Exhaust ventilation is necessary in restrooms to remove moisture and to prevent restroom odors from penetrating into adjacent areas.

Conclusions/Recommendations

As reported by Chief Walker, the planned renovations to the building should remove any existing water damaged/mold colonized building materials and prevent further water damage.

In view of the findings at the time of the visit, the following recommendations are made:

1. Ensure exposed/damaged pipe insulation material in the basement is encapsulated/remediated in conformance with all applicable Massachusetts laws.
2. Ensure doors with access to the engine bay fit completely flush with threshold. Seal doors on all sides with foam tape and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
3. Ensure utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.

4. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
5. Ensure that moss growth/water-stained exterior brick are cleaned and disinfected.
6. Continue with plans to replace roof and ceiling tile systems. Particular attention should be made to examine areas of water leaks for microbial growth. Disinfect these areas with an appropriate antimicrobial as necessary.
7. Repair breaches in the building envelope including, cracks in walls, missing/damaged flashing and open utility holes.
8. Make repairs to windows to eliminate spaces around frames.
9. Unclog exterior drain and inspect regularly for proper drainage.
10. Replace damaged exterior door for rear entrance.
11. Reactivate bathroom exhaust vents, repair/replace motors as needed.
12. Consult "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (US EPA, 2001) for further information on mold and/or mold clean up. Copies of this document are available from the US EPA at: http://www.epa.gov/iaq/molds/mold_remediation.html.

13. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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Picture 1

Water Damaged/Mold Colonized Ceiling Tiles and Fiberglass Insulation

Picture 2

Close-Up of Water Damaged/Mold Colonized Fiberglass Insulation

Picture 3

Water Damaged/Mold Colonized Ceiling Tiles and Fiberglass Insulation

Picture 4

Mold Colonized Pipe Insulation in Basement

Picture 5

Entrance to Station 2, Note Lack of Gutter/Downspout System Resulting in Moss Growth/Discoloration of Brick

Picture 6

Close-Up of Moss Growth/Discoloration of Brick in Preceding Picture

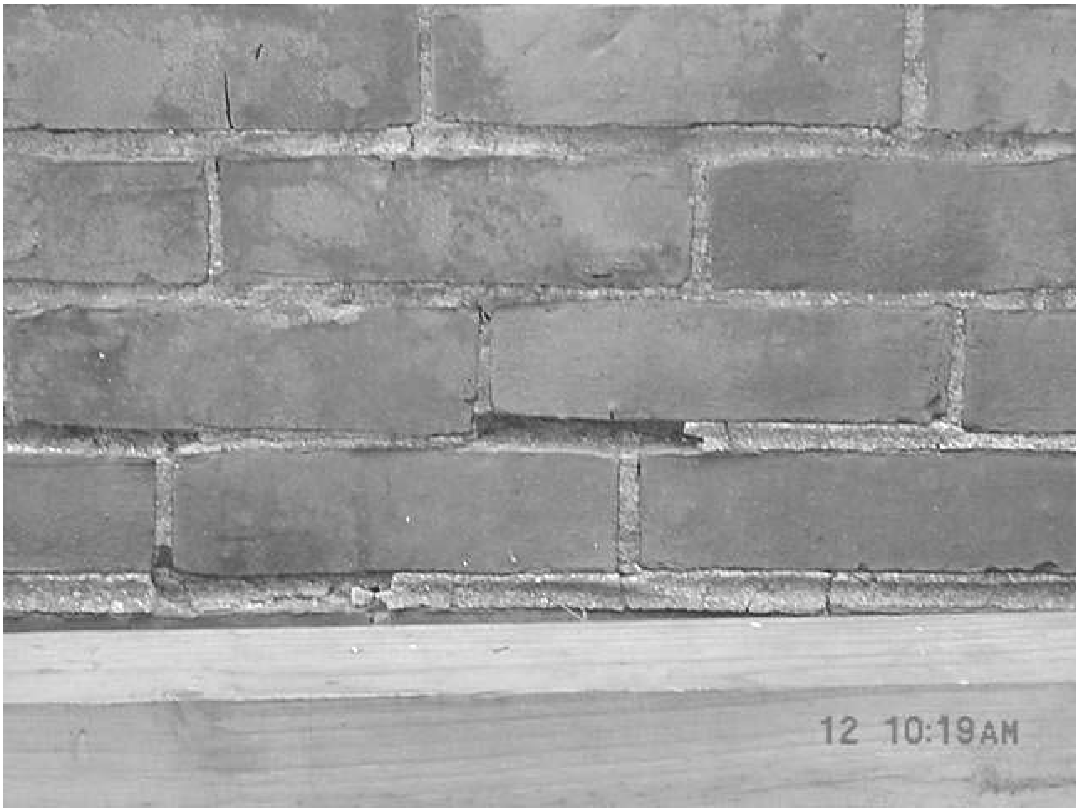
Picture 7

Clogged Drain

Picture 8

Severely Corroded Door Sealed with Plastic Sheeting

Picture 9



Moss Growth and Missing/Damaged Mortar on Rear of Building

Picture 10

Moss Growth and Missing/Damaged Mortar on Rear of Building

Picture 11

Open Utility Hole around Water Spigot

Picture 12

Utility Hole around Pipe

Picture 13

Spaces between Brick and Window Frames

Picture 14

Spaces between Brick and Window Frames

Picture 15

Local Exhaust Ventilation System in Engine Bay

Picture 16

Pressurized Cuff on Tailpipe for Local Ventilation System

Picture 17

Spaces under Door off Engine Bay

Picture 18

Damaged/Exposed Pipe Insulation in Basement

Picture 19

Damaged/Exposed Pipe Insulation in Basement

Picture 20

Exhaust Vent in Bathroom Sealed to Prevent Drafts

TABLE 1

Indoor Air Test Results – Fire Dept. Station 2, South Ave. Rt. 30, Weston, MA – May 12, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background	415	60	22					Sunny, clear skies, NW winds 15-20 mph, moderate traffic
Kitchen	518	68	36	3	Y	N	N	Water damaged ceiling tiles, gas stove
Main Hallway	416	68	34					Water damaged ceiling tiles, visible mold growth on insulation
Watch Desk	426	67	34	1	Y	N	N	Spaces around/beneath engine bay door
Engine Bay	351	65	30		Y	Y	Y	Local exhaust system
Shop Area	361	63	31		Y	N	N	
Exercise Room	434	65	38		N	Y	N	Passive vent, space under door (engine bay)
Bedroom 1	390	65	39		Y	N	N	Water damaged ceiling tiles
Bedroom 2	405	65	40		Y	N	N	Water damaged ceiling tiles
Bedroom 3	397	65	40		Y	N	N	Water damaged/missing ceiling tiles, exposed fiberglass insulation
Storage Room	417	64	43		Y			Water damaged ceiling tiles, water damaged boxes

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results – Fire Dept. Station 2, South Ave. Rt. 30, Weston, MA – May 12, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Restroom	462	66	42		Y	Y	Y	Motor to exhaust vent removed, covered to prevent backdrafting
Basement	427	64	46		Y			Moldy pipe wrap, exposed/damaged pipe insulation
Outside Perimeter/Exterior								Moss growth/backsplash on exterior brick, lack of gutters/downspouts, missing/damaged around brick, open utility holes, spaces around window frames, missing/damaged caulking/sealant

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
Station 2, South Ave. Rt. 30, Weston, MA – May 12, 2005

Location	Carbon Monoxide (**ppm) Before	Carbon Monoxide (**ppm) After	Ultrafine Particulates $1000p/cc^3$ Before	Ultrafine Particulates $1000p/cc^3$ After	Comments
Background	ND	ND	5.9	6.2	Sunny, clear skies, NW winds 15-20 mph, moderate traffic
Kitchen	ND	ND	5.9	6.4	
Watch Desk	ND	ND	5.2	18.7	
Engine Bay	ND	ND	5.3	9.5	
Exercise Room	ND	ND	6.0	6.4	
Bedroom 1	ND	ND	5.4	5.4	
Bedroom 2	ND	ND	5.9	6.0	Exhaust emissions "trapped"-strong odors
Storage Room	ND	ND	5.2	4.9	

**** ppm = parts per million parts of air**
*** testing before and after starting diesel engines and response vehicles for simulated call**